

10/576619

Docket No.: 2003P15803

IAP20 Receipt Date 21 APR 2006

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1AP20 REC'D FPO 21 APR 2006

1 Description

2

3 Coupling structure for cylindrical resonators

4

5 The present invention relates to a filter element suitable for
6 filtering electromagnetic waves, in particular a bandpass fil-
7 ter or band-stop filter, implemented also as a reflection fil-
8 ter or suchlike, containing a dielectric, cylindrical resona-
9 tor and one or more lines which supply or, as the case may be
10 draw off electromagnetic waves to/from the dielectric resona-
11 tor, with said lines terminating in a suitable contacting
12 structure. The present invention relates also to an oscillator
13 constructed using a filter element of said type.

14

15 Commercially available resonators, which is to say oscillating
16 systems whose individual elements are tuned to a required
17 (natural) frequency so that the resonator will oscillate at
18 that frequency when excited, have many uses in both low-
19 frequency and high-frequency technology. Depending on their
20 physical design, material, and shape they are suitable, for
21 example, as a very simple (narrowband) filter, as a frequency-
22 determining element of an oscillator, for measuring material
23 characteristics in the HF field, or as a short-term electro-
24 magnetic-energy storage (employed in particle accelerators).

25

26 Microstrip-line resonators, cavity resonators, or what are
27 termed dielectric resonators embodied, that is to say, for the
28 most part from a ceramic material are employed in the area of
29 high-frequency technology depending on the specific applica-
30 tion. The last-mentioned resonators are frequently used having
31 a cylindrical shape as electrical or, as the case may be,
32 electromagnetic filters and hence also as filters for generat-
33 ing oscillations in resonator circuits. The therein achievable

1 characteristics of filters of said type and hence also of the
2 oscillators produced using them (for example their power lev-
3 els and noise characteristics) are, however, crucially depend-
4 ent on the coupling of the dielectric resonator to the supply
5 lines or, as the case may be, draw lines.

6
7 Cylindrical dielectric resonators are presently mounted on a
8 printed-circuit board predominantly with one of their flatly
9 embodied end faces spaced at a certain distance from the top
10 side thereof. Located on said top side of the printed-circuit
11 board are one or more lines which supply or, as the case may
12 be, draw off electromagnetic waves to/from the dielectric
13 resonator. A typical structural design often used in products
14 such as, for instance, local oscillators and filters for radar
15 systems, satellite receivers, and wireless distribution ser-
16 vices for digital television such as local multipoint distri-
17 bution services (LMDS) and suchlike is outlined in Fig. 8.

18
19 The structural design shown in Fig. 8 can lead to serious
20 problems in the production of oscillators in the presence of
21 increasing operating frequencies in particular in what is
22 termed the K band, which is to say in the microwave range of
23 18-26.5 GHz. The energy coupled over from the first line into
24 the second line is here in most cases not sufficient to enable
25 oscillator circuits to start oscillating. That is why only os-
26 cillators having operating frequencies below 18 GHz are pro-
27 duced in most practical applications having ceramic resonators
28 of said kind.

29
30 The object of the invention is to provide a resonator circuit
31 for a filter element for filtering electromagnetic waves which
32 element avoids the disadvantages cited at the beginning. The
33 aim in this regard is to disclose improved coupling of the

1 line(s) to cylindrical, dielectric resonators, in particular
2 for oscillators, preferably for operating frequencies above 18
3 GHz.

4
5 Said object is achieved by means of a filter element for fil-
6 tering electromagnetic waves which element has the features
7 according to Claim 1 and by means of an oscillator having the
8 features according to Claim 14. Advantageous embodiments and
9 developments that can be employed either alone or in mutual
10 combination are the subject of the dependent Claims.

11
12 The invention builds on filter elements of the cited class for
13 filtering electromagnetic waves which elements contain a di-
14 electric, cylindrical resonator and one or more lines termi-
15 nating in a contacting structure and supplying or, as the case
16 may be drawing off electromagnetic waves to/from the dielec-
17 tric resonator initially in that said resonator is located
18 variably spaced from the lines, with spacings being conceiv-
19 able in either the negative or, alternatively, the positive
20 longitudinal direction (z-axis) of the resonator.

21
22 In the first-cited case, which is to say when the spacing is
23 in the resonator's negative longitudinal direction, the lines
24 together with their contacting structure preferably form part
25 of a printed-circuit board that supports the resonator, with a
26 recess in which the resonator is located by means of a suit-
27 able securing means being inventively provided in said
28 printed-circuit board.

29
30 In the case cited as an alternative, which is to say when the
31 spacing is in the resonator's positive longitudinal direction,
32 located in the contacting structure's close proximity is any
33 object or a device, for example a retention area, a cover, or

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1 suchlike that holds the resonator in place, with a recess in
2 which the resonator is located by means of a suitable securing
3 means being inventively provided in said retention area or, as
4 the case may be, cover etc.

5
6 Owing to the resonator's inventively variably spaced contact-
7 ing the transmittable signal power is advantageously substan-
8 tially increased compared to previous structures according to,
9 for example, Fig. 8. Secure excitation and stable operation of
10 an oscillator produced using a filter element of said type can
11 be achieved thereby under practical operating conditions, in
12 particular over a wide temperature range.

13
14 A retention area or, as the case may be, cover etc. having a
15 recess holding the resonator in place on the face can, more-
16 over, also be provided in cases in which the resonator is ad-
17 ditionally partially "sunk" into a recess on the printed-
18 circuit board, which is to say is located spaced in the nega-
19 tive longitudinal direction from the lines terminating in a
20 contacting structure. A physical design of said type on the
21 one hand facilitates assembling of the printed-circuit board
22 and cover etc. and, on the other hand, results advantageously
23 in what are termed ultra-compact units of the kind always of
24 interest to the automobile industry in particular.

25
26 The recess in the printed-circuit board or, as the case may
27 be, in the previously mentioned device (surface element,
28 cover, etc.) is preferably dimensioned in such a way as to en-
29 able the resonator to be fitted or, as the case may be,
30 mounted in a self-centering manner, for example is embodied at
31 least on the ingress side slightly conically or provided with
32 a folded edge or, as the case may be, chamfer.

33

1 An adhesive or silicon or suchlike is preferably used as the
2 means for securing the resonator.

3

4 Each line preferably terminates in each case in a separately
5 embodied contacting structure. Two or more lines can alterna-
6 tively also terminate in a commonly embodied contacting struc-
7 ture.

8

9 The contacting structure can preferably be embodied at least
10 in sections as sickle-shaped, as a result of which a certain
11 desired filter characteristic can advantageously be achieved.
12 As mentioned at the beginning, it is crucial for operating
13 filter elements of said type or, as the case may be, oscilla-
14 tors constructed therefrom that sufficient signal power is
15 emitted or transmitted by the line or, as the case may be,
16 lines.

17

18 The contacting structure can alternatively preferably be em-
19 bodied as a 360° annulus or, again as an alternative, as a cir-
20 cular-arc segment having a variable aperture angle less than
21 360° . In particular in the last-cited case the coupling effi-
22 ciency between the line or, as the case may be, lines and the
23 resonator can advantageously be accommodated and undesired
24 phase jitter minimized by skillfully selecting the aperture
25 angle α . Contacting structures having an aperture angle α of
26 approximately 160° have, for instance, proved effective when
27 there are two lines, contacting structures having an aperture
28 angle of approximately 110° have proved effective when there
29 are three lines, and contacting structures having an aperture
30 angle of, for instance, approximately 75° have proved effective
31 when there are four lines, with the above angles being only
32 examples of possible embodiments.

33

1 In a development of the invention the contacting structure has
2 larger dimensions than the cylindrical resonator. In order to
3 minimize structural size and/or increase coupling efficiency,
4 as an alternative thereto and provided the resonator is lo-
5 cated on the retention area or, as the case may be, cover
6 etc., the contacting structure can also have smaller dimen-
7 sions than the cylindrical resonator.

8
9 The resonator is to practical advantage oriented substantially
10 to be centered relative to the contacting structure or, as the
11 case may be, located in the central area thereof, with coarser
12 deviance tolerances advantageously being allowed in the reso-
13 nator's positioning in the case of contacting according to the
14 present invention than is the case with conventional circuits
15 where relatively slight deviations can result in the resonator
16 circuit's non-serviceability and hence rejection.

17
18 The present invention is particularly suitable for dielectric,
19 cylindrical resonators of a filter element having operating
20 frequencies above 18 GHz. Said invention further relates to an
21 oscillator, in particular for radar systems, LMDS distribution
22 services, satellite receivers, and suchlike, containing a pre-
23 viously described filter element for filtering electromagnetic
24 waves. In this way the invention also displays its advantages
25 within the scope of an overall system.

26
27 The invention will now be explained in an exemplary manner
28 with reference to the accompanying drawings and the aid of
29 preferred embodiments.

30
31 Fig. 1 is a schematic plan view of a first structure of a
32 filter element containing a cylindrical resonator to
33 which is ducted a line at whose end a sickle-shaped

1 contacting structure is embodied;

2
3 Fig. 2 is a schematic plan view of a second structure of a
4 filter element containing a cylindrical resonator to
5 which is ducted a line at whose end a an annular
6 contacting structure is embodied;

7
8 Fig. 3 is a schematic plan view of a third structure of a
9 filter element containing a cylindrical resonator to
10 which are ducted two lines at whose ends a separate
11 sickle-shaped contacting structure is in each case
12 embodied;

13
14 Fig. 4 is a schematic plan view of a fourth structure of a
15 filter element containing a cylindrical resonator to
16 which are ducted two lines terminating in a common
17 sickle-shaped contacting structure;

18
19 Fig. 5 is a schematic side view of the structure of a fil-
20 ter element according to one of preceding Figures 1
21 to 4 or 8 having a resonator inventively located on
22 a cover and variably spaced from the contacting
23 structure along the positive z-axis;

24
25 Fig. 6 is a schematic side view of the structure of an os-
26 cillator according to one of preceding Figures 1 to
27 4 or 8 having a resonator conventionally located on
28 the contacting structure;

29
30 Fig. 7 is a schematic side view of the structure of a fil-
31 ter element according to one of preceding Figures 1
32 to 4 or 8 having a resonator inventively located in
33 a recess in the printed-circuit board and variably

1 spaced from the contacting structure along the nega-
2 tive z-axis; and
3

4 Fig. 8 is a schematic plan view of conventional structure
5 of a filter element containing a cylindrical resonator
6 to which are ducted two supply lines.
7

8 In the following description of the preferred embodiments of
9 the present invention the same reference numerals refer to the
10 same or comparable components.
11

12 Fig. 1 is a top view of a first structure of a filter element
13 containing a cylindrical, dielectric resonator 1 to which is
14 ducted a supply line 2 at whose end a sickle-shaped contacting
15 structure 4 is embodied. The sickle-shaped contacting struc-
16 ture 4 consists of a circular-arc segment having a variable
17 aperture angle α to which is connected a customary line 2. For
18 the example shown in Fig. 1 the aperture angle α is approxi-
19 mately 160° . The width of the line 2 and of the sickle-shaped
20 contacting structure 4 can be accommodated to the relevant
21 conditions and is to be regarded as being variable. One (see
22 Fig. 4), two (see Fig. 3), or more (not shown) contacting
23 structures 4, 4a, 4b can in particular be attached to the di-
24 electric, ceramic resonator 1. This only requires accommodat-
25 ing the aperture angles α of the individual contacting struc-
26 tures accordingly.
27

28 The sickle-shaped contacting structure 4, 4a, 4b can, in par-
29 ticular in the case of the resonator's arrangement shown in
30 Fig. 5 in relation to the contacting structure, also assume
31 dimensions that are smaller than the dimensions of the cylin-
32 drical resonator 1. In that case the cylindrical resonator 1
33 covers the metallic contacting structures 4, 4a, 4b at least

1 partially.

2
3 Fig. 2 is a top view of a second structure of a filter element
4 containing a cylindrical resonator 1 to which is ducted a line
5 2 at whose end an annular contacting structure 4 is embodied.
6

7 Fig. 3 is a top view of a third structure of a filter element
8 containing a cylindrical resonator 1 to which are ducted two
9 lines 2, 3 at whose ends a separate sickle-shaped contacting
10 structure 4a, 4b is in each case embodied, with the two con-
11 tacting structures 4a, 4b being mutually electrically iso-
12 lated. Contacting structures of said type are suitable par-
13 ticularly in the case of feedback circuits for producing os-
14 cillators: The cylindrical resonator 1 is employed in said
15 circuits as a narrowband bandpass filter which, for example,
16 in a defined mode is only permeable for a certain frequency,
17 which is why in this connection the term multi-mode bandpass
18 filter is also used, because, for example, the basic mode or
19 higher-order modes can be used. The resonator 1 is for this
20 purpose, as shown in Fig. 3, contacted with two lines 2, 3. It
21 is crucial for the oscillator's operation that sufficient sig-
22 nal power is emitted or transmitted by the first line 2 to the
23 second line 3. This is ensured by the sickle-shaped contacting
24 structures 4a, 4b.

25
26 Fig. 4 is a top view of a fourth structure of a filter element
27 containing a cylindrical resonator 1 to which are ducted two
28 lines 2, 3 terminating in a common sickle-shaped contacting
29 structure 4. Structures of said type in which the supply lines
30 2, 3 share a sickle-shaped contacting structure 4, 4a, 4b are
31 suitable particularly as band-stop filters.

32
33 Fig. 5 is a side view of the structure of a filter element ac-

1 cording to one of preceding Figures 1 to 4 or 8 having a reso-
2 nator 1 inventively located on, for example, a cover 5 and
3 variably spaced from the contacting structure contacting
4 structure 4, 4a, 4b in the positive direction of the z-axis.
5

6 Fig. 6 is a side view of the structure of a filter element ac-
7 cording to one of preceding Figures 1 to 4 or 8 having a reso-
8 nator 1 conventionally located on, in particular pasted onto
9 the contacting structure 4, 4a, 4b.

10
11 Finally, Fig. 7 is a side view of the structure of a filter
12 element according to one of preceding Figures 1 to 4 or 8 hav-
13 ing a resonator 1 inventively located in a recess 8 in the
14 printed-circuit board 6 and variably spaced from the contact-
15 ing structure 4, 4a, 4b in the negative direction of the z-
16 axis.

17
18 This means that the height of the cylindrical ceramic resona-
19 tor 1 (which, incidentally, is sometimes also referred to as a
20 pill) above the surface of a printed-circuit board 6 does not,
21 according to the invention, have to be defined; it is vari-
22 able. The electrical or, as the case may be, electromagnetic
23 characteristics of the structure can hence be additionally
24 tuned.

25
26 The cylindrical resonator 1 can be mechanically secured with
27 the aid of a suitable securing material, in particular an ad-
28 hesive 7 or suchlike, to any object 5 that can be, for exam-
29 ple, a simple retention area located in close proximity to the
30 surface of the printed-circuit board 6 (see Fig. 5). Said ob-
31 ject 5 is advantageously a cover as is required to be embodied
32 above the pill (which is to say in the positive z direction)
33 in virtually all practical instances in the embodiment of os-

1 cillator circuits or electrical or, as the case may be, elec-
2 tromagnetic filters. Said cover can be embodied from, for ex-
3 ample, metal or absorbent materials such as, for example,
4 plastic.

5
6 Alternatively - or, where applicable, additionally (not shown)
7 - thereto the cylindrical ceramic resonator 1 can inventively
8 even be located in the negative value range relative to the
9 contacting structure 4, 4a, 4b, in particular - as shown in
10 Fig. 7 - if a recess 8 for the resonator 1 is embodied in the
11 printed-circuit board 6. Particularly advantageous therein are
12 embodiments of recesses 8 allowing a kind of self-centering
13 mounting of the resonator 1 relative to the contacting struc-
14 ture 4, 4a, 4b. It is again mentioned though only as a supple-
15 mentary remark that in the embodiment of oscillator circuits a
16 cover (not shown) is required to be embodied above the pill
17 (which is to say in the positive z direction) of filter ele-
18 ments of said type.

19
20 The invention includes the arrangement of a resonator 1 varia-
21 bly spaced from a contacting structure 4, 4a, 4b containing
22 one, two, or more supply or, as the case may be, draw lines 2,
23 3. With the present invention the transmitted signal power can
24 be advantageously substantially increased compared to conven-
25 tional coupling structures (see again the bandpass filter
26 shown in Fig. 8). Secure excitation and stable operation of an
27 oscillator produced using a filter element of said type can be
28 achieved thereby under practical operating conditions (for ex-
29 ample over a wide temperature range).

30
31 The positioning accuracy of the cylindrical resonator 1 is
32 very low. This allows simple and economical production during
33 which the resonator 1 only has to be pasted into the prefera-

1 bly self-centering central area of at least one recess 8 sur-
2 rounded by the contacting structure 4, 4a, 4b.

3

4 The present invention has been described using a filter ele-
5 ment having a cylindrical, dielectric resonator 1. The inven-
6 tion is not, though, restricted to said type of resonator. In
7 particular any type whatsoever of rotationally symmetric reso-
8 nator - whether embodied as being solid ("disk-type") or hol-
9 low-bodied or, as the case may be, partially hollow-bodied
10 ("cylinder-type") - can be the subject of inventive contacting
11 structures.

12

13 The present invention is particularly suitable for use in os-
14 cillator circuits having operating frequencies above 18 GHz,
15 such as are typically increasingly used in a motor vehicle's
16 environment systems such as Lane Departure Warning (LDW),
17 Blind Spot Detection (BSD), and Rear View Detection etc.

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